

## PATENT COOPERATION TREATY

## PCT

## INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference <b>PHN 17.556W0</b>	<b>FOR FURTHER ACTION</b> see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. <b>PCT/EP 00/06816</b>	International filing date (day/month/year) <b>17/07/2000</b>	(Earliest) Priority Date (day/month/year) <b>22/07/1999</b>
Applicant <b>KONINKLIJKE PHILIPS ELECTRONICS N.V. et al.</b>		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.



It is also accompanied by a copy of each prior art document cited in this report.

## 1. Basis of the report

- a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.



the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

- b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :



contained in the international application in written form.



filed together with the international application in computer readable form.



furnished subsequently to this Authority in written form.



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the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.



the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ **Certain claims were found unsearchable** (See Box I).

3. ☐ **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

the text is approved as submitted by the applicant.



the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

the text is approved as submitted by the applicant.



the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No.

as suggested by the applicant.



because the applicant failed to suggest a figure.



because this figure better characterizes the invention.

1E



None of the figures.

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 00/06816

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G01R33/09 H01L45/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G01R H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, COMPENDEX, INSPEC

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 762 389 A (FUJITSU LTD) 12 March 1997 (1997-03-12) column 13, line 52 -column 14, line 29; claims 17,18; figures 6A-C -----	1-3,6
A	US 5 820 924 A (BOHLINGER MICHAEL J ET AL) 13 October 1998 (1998-10-13) claims 1,2 -----	1-3
A	US 5 416 353 A (KAMIGUCHI YUZO ET AL) 16 May 1995 (1995-05-16) column 6, line 40 - line 52 column 7, line 8 - line 10 -----	1



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
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\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search

6 December 2000

Date of mailing of the international search report

12/12/2000

Name and mailing address of the ISA

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0762389 A	12-03-1997	JP 9069210 A KR 250555 B US 5761010 A	11-03-1997 01-04-2000 02-06-1998
US 5820924 A	13-10-1998	NONE	
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**Published:**

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- Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.

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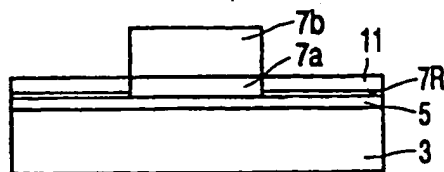
(75) Inventors/Applicants (*for US only*): ADELERHOF, Derk, J. [NL/NL]; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). COELHOORN, Reinder [NL/NL]; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). VAN ZON,

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*



WO 01/07926 A1

(54) Title: METHOD OF MANUFACTURING A MAGNETIC TUNNEL JUNCTION DEVICE



(57) Abstract: A method of manufacturing a magnetic tunnel junction device, in which a stack (1) comprising two magnetic layers (3, 7) and a barrier layer (5) extending in between is formed. One of the magnetic layers is structured by means of etching, in which, during etching, a part of this layer is made thinner by removing material until a rest layer (7r) remains. This rest layer is passivated by chemical conversion. In the relevant method, it is prevented that the magnetic layer which is not to be structured is detrimentally influenced during structuring of the other magnetic layer.

Method of manufacturing a magnetic tunnel junction device.

The invention relates to a method of manufacturing a magnetic tunnel junction device, in which a stack comprising two magnetic layers and a barrier layer extending in between is formed.

5 The invention also relates to a magnetic tunnel junction device obtainable by means of such a method, a magnetic field sensor provided with such a device and a magnetic memory provided with such a device.

10 A device as described above is disclosed in WO-A 99/22368. The magnetic tunnel junction device known from said patent application comprises a first and a second magnetic layer, which layers are sandwiched with respect to an insulating intermediate layer and serve as electrode layers. As a transducing element, this device forms part of a magnetic field sensor provided with a magnetic yoke, in which the first magnetic layer is in direct contact with a part of the yoke. The first magnetic layer, likewise as the yoke, is formed from a soft-magnetic material. The second magnetic layer is a composite layer and comprises a ferromagnetic sub-layer and a pinning structure. The insulating intermediate layer constitutes a tunnel barrier.

20 In the known magnetic tunnel junction device, one of the magnetic layers, namely the soft-magnetic layer, therefore also serves as a flux guide. To prevent detrimental effects on the magnetical properties of this layer, such as domain wall formation due to irregularities in the surface of the soft-magnetic layer facing the tunnel barrier, it is desirable that only the other magnetic layer, i.e. the second magnetic layer, and possibly the barrier-forming intermediate layer, is, or are, structured.

25 It is an object of the invention to provide a method of the type described in the opening paragraph, comprising a process of structuring one of the magnetic layers, which process stops with certainty before the other magnetic layer is reached.

To achieve the object described, the method according to the invention is characterized in that one of the magnetic layers is structured by means of etching, in which, during etching, a part of the relevant layer is made thinner by removing material until a rest layer remains, whereafter the electrical resistance of the rest layer is increased by chemical

etching. These known etching methods have proved to be eminently suitable for the method according to the invention.

An embodiment of the method according to the invention is characterized in that the magnetic layer to be structured is built up from, consecutively, a basic layer and a layer structure comprising at least a further layer for magnetic pinning of the basic layer. The basic layer may be a ferromagnetic layer, for example, of an NiFe alloy or a Co alloy, particularly a Co-Fe alloy, while the pinning layer structure may comprise one of the following possibilities: an anti-ferromagnetic layer of, for example, an FeMn alloy or an IrMn alloy; a hard-magnetic ferromagnetic layer of, for example, a Co alloy; an artificial anti-ferromagnetic structure comprising two anti-parallel magnetic layers separated by a metallic intermediate layer. Such a structure may be coupled to an anti-ferromagnetic layer of, for example, an FeMn alloy. If such a magnetic layer to be structured is formed, it is preferred to selectively etch the layer structure, particularly selectively chemically etch this structure before etching, particularly physical etching takes place, until the basic layer is reached. By making partly use of said selective etching, the structuring process in accordance with the method according to the invention can be performed within a shorter period of time. Selective chemical etching is a known etching technique.

It is to be noted that the method according to the invention implies a method of structuring a magnetic electrode layer of a semi-manufactured product of a magnetic tunnel junction device, in which the semi-manufactured product comprises an assembly of said electrode layer, a barrier layer and a further magnetic electrode layer. In the last-mentioned method, the structuring of the relevant layer does not influence the magnetical properties of the other magnetic electrode layer of the magnetic tunnel junction device, at least not in a detrimental sense. The special aspect of this method, in which etching is used, is that etching does not take place as far as the barrier layer of the magnetic tunnel junction device, but the etching process is stopped at such an earlier moment that a rest layer remains on the barrier layer. It is thereby ensured that, in spite of layer thickness variations and variations of etching methods, the magnetic electrode layer, which is not to be structured, is not etched. The barrier layer, which is an insulating layer, a layer having a low electrical conductance, or an electric layer, is usually only approximately 1 nm thick.

The magnetic tunnel junction device according to the invention, manufactured by means of the method according to the invention, has a magnetic layer structured by means of this method and another magnetic layer which may be or may comprise a soft-magnetic layer, which layer is usable as a flux guide. Such a soft-magnetic layer may be formed from,

conducting or dielectric layer 5, in this document also referred to as barrier layer, of, for example  $\text{Al}_2\text{O}_3$ , a second magnetic layer 7 built up in this example of a basic layer 7a of a soft-magnetic material, in this example an NiFe alloy, and a layer structure 7b comprising at least a further layer of an anti-ferromagnetic material such as an FeMn alloy. Alternatively, a hard-magnetic layer may be used as a second magnetic layer for the layer structure comprising the basic layer 7a and the layer structure 7b. During the method according to the invention, a shielding layer 9 of, for example, a photoresist, see Fig. 1B, is provided on the stack 1 shown. Subsequently, etching processes are used, in which the layer structure 7b is first etched selectively, particularly etched chemically, until the basic layer 7a is reached; see Fig. 1C.

10 Subsequently, the basic layer 7a is etched, particularly etched physically, until a rest layer 7r of soft-magnetic material remains; see Fig. 1D. Alternatively, instead of two etching processes, it may be sufficient to use physical etching only, such as sputter etching. Physical etching is preferably also used if the second magnetic layer 7 is a hard-magnetic layer.

The rest layer 7r obtained in one of the methods described above preferably has a thickness of up to 5 nm maximum. During the method according to the invention, the rest layer 7r is exposed to oxidation in this embodiment so as to increase the electrical resistance of the relevant layer. The rest layer 7r is then converted into an oxide layer 7R which comprises Ni and Fe oxides in this example; see Fig. 1E. When using nitridation, a nitride layer 7R is obtained. In this example, thermal oxidation or plasma oxidation is preferably used for this conversion. By depositing an insulating material such as  $\text{SiO}_2$ , a protective layer 11 may be formed on the oxidation layer 7R. The shielding layer 9 may be removed.

15 20

The magnetic field sensor according to the invention, shown in Fig. 2, comprises a magnetic tunnel junction device 20 of the type shown in Fig. 1E. In this embodiment, the sensor also comprises a magnetic yoke 22 which has an interruption 22a which is bridged and is in magnetic contact with the tunnel junction device 20. The magnetic yoke 22 is formed from a soft-magnetic material such as an NiFe alloy. The sensor has a sensor face 24 adjacent to a non-magnetic transducing gap 26. The interruption 22a and the gap 26 are formed by insulating layers of, for example  $\text{SiO}_2$  or  $\text{Al}_2\text{O}_3$ .

25

It is to be noted that the invention is not limited to the embodiments shown. For example, variants of the several steps of the method are possible within the scope of the invention. Furthermore, the sensor shown may be formed as a magnetic head for scanning a magnetic recording medium. Such a construction may form part of a combined read/write head. The magnetic tunnel junction device obtained in accordance with the method of the invention may also form part of a magnetic memory.

30

9. A magnetic tunnel junction device as claimed in claim 8, in which the layer other than the structured magnetic layer comprises a soft-magnetic layer which is usable as a flux guide.
- 5 10. A magnetic field sensor provided with the magnetic tunnel junction device as claimed in claim 8.
11. A magnetic field sensor as claimed in claim 9, provided with a magnetic yoke which is in magnetic contact with the soft-magnetic layer of the magnetic tunnel junction  
10 device.
12. A magnetic memory provided with the magnetic tunnel junction device as claimed in claim 8.



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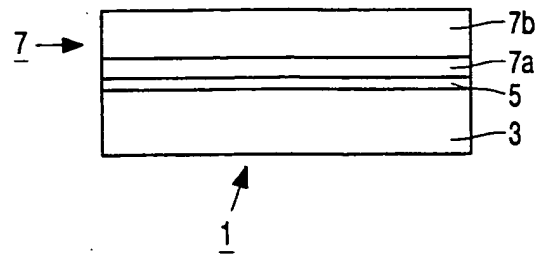


FIG. 1A

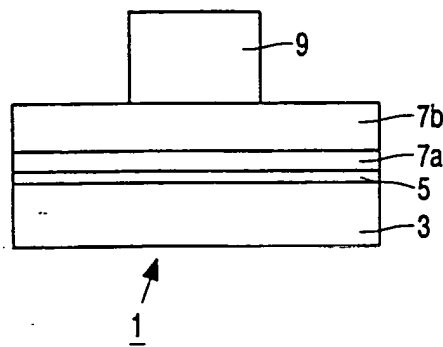


FIG. 1B

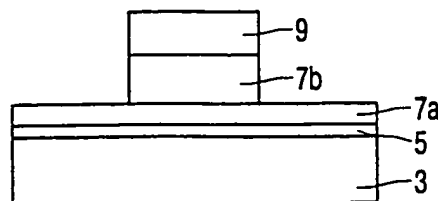


FIG. 1C

2/2

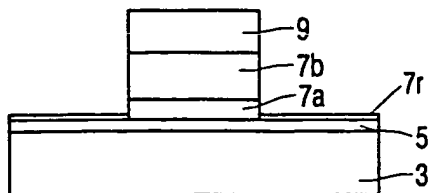


FIG. 1D

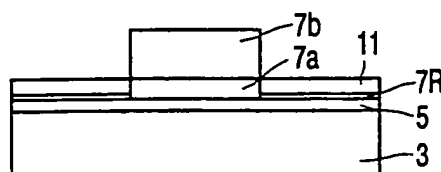


FIG. 1E

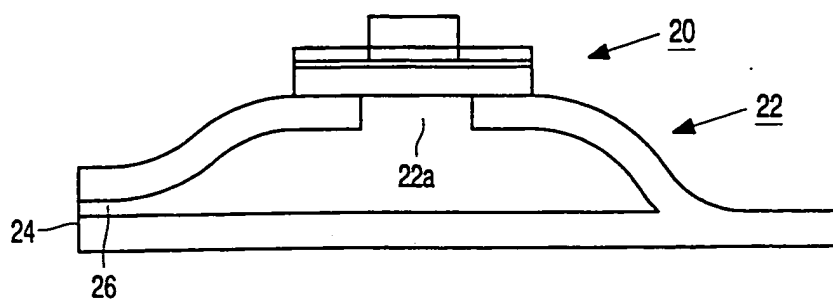


FIG. 2

# INTERNATIONAL SEARCH REPORT

Internati      Application No  
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**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7    G01R33/09    H01L45/00

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

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Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 762 389 A (FUJITSU LTD) 12 March 1997 (1997-03-12) column 13, line 52 -column 14, line 29; claims 17,18; figures 6A-C	1-3,6
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Date of the actual completion of the international search

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